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Washington, D. C.

"CONTEMPORARY CIVILIZATION AND ITS CHALLENGE TO SCHOOLS OF TOMORROW"

Freedom and science are two words that come with increasing frequency from the lips of men. Freedom has been concerned with political freedom, with the right of free speech, and the freedom to worship as one's conscience dictates. Within the last few decades, these two basic freedoms have been related to two other fundamental freedoms, namely, the freedom from want and the freedom from fear. The people of Asia and two hundred millions in Africa are either in their swaddling clothes with respect to freedom or are demanding its birth. These people are not only looking forward to a higher standard of living with freedom from want; they are demanding it. The new freedom is being sought by the underdeveloped countries at a time when the world is divided between two great ideologies: The ideology of a democracy and the ideology of totalitarian government.

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These underdeveloped countries are looking to science and technology to achieve this goal of freedom. The big question today is whether these underdeveloped countries will work out the answer to this fundamental question within the framework of democracy or within the framework of totalitarian government.

The standard of living enjoyed by our own country today makes tremendous demands upon the resource base not only of our own country but great demands upon resources of countries great distances from us.

The United States today, with approximately seven per cent of the world's population, is consuming about 50 per cent of the world's goods. In fact the United States is so rich that it can consume about two-thirds of the world's production of oil, leaving only one-third for all of the other countries. The very high consumption of the world's available resources by the United States will increasingly meet competition from many parts of the world where there is an insistent demand for a higher standard of living, which will not be denied. The United States has been thrust into the leadership of the world by two world wars. It is difficult to see the possibility of any other leader for a long period of time —perhaps several centuries. Basically this means that we have become on a world-wide scale our brother's keeper, or shall we say democracy's guardian. This means accepting the responsibility for helping the underdeveloped countries conquer their poverty and disease within the framework of democracy. Leadership is a very simple role to discern but an awful responsibility to live up to. We did not seek the position of world leadership but it is our destiny to fulfill it.

In the world of science, man's greatest achievement has been the realization that he lives in a consistent universe; that is, if he asks nature a question by way of experiment at two different times and the conditions of the experiment are the same, nature will give identical answers on both occasions. The path from the concept of a universe ruled by caprice to the concept of law is a long and difficult one. Gradually a body of knowledge which we now call science has been established.

Professor Niels Bohr, distinguished atomic physicist of Denmark, has described this body of knowledge as resulting from "the finding of techniques that have enabled man to place limiting values on his preconceptions."

The important thing to notice in Professor Bohr's statement is that it is not the preconception which is most important in science but the techniques by which man can determine the limitations for his preconception. May I give you an example from my own personal experience? My professional research has been in the field of female sex hormones. These are chemical substances which have now been isolated in crystalline form. They are elaborated in the ovary, carried by the blood stream to distant parts of the body where they bring about a growth and development of the uterus and the breasts in the female. It occurred to me that when animals become sexually mature, physical growth ceases. I therefore developed a preconception that the cessation of physical growth might be due at least in part to the elaboration of sex hormones within the body. To test out this preconception a number of young rats, thirty days of age, were injected for a period of three months with sex hormone dissolved in a small quantity of oil. The animals were weighed once a week. The results were compared with the growth curve of animals which had been only injected with the oil. Those rats injected with the sex hormone lagged far behind in their growth rate. In other words, the preconception was validated by the technique. Dr. Doisy of Saint Louis University carried out exactly the same experiment. He had developed a preconception that the spurt in growth which seems to take place at about the time of puberty might be due to the presence of sex hormones. This preconception is the exact opposite of the one which I started with. He designed and carried out an experiment almost exactly the same as the one which I carried out. To his surprise he found, that so far from stimulating growth, the hormones inhibited growth. You see therefore that the fact that we started out with different preconceptions is of no consequence. The important thing is that we found exactly the same facts. In the one case the preconception was validated; in the other one the preconceptions were found not to be true. But the important thing is that the basic scientific information was the same in both cases.

Let us contrast this with a conception of art which may be defined as a body of accomplishment obtained by realizing preconceptions. If you would paint a portrait of Abraham Lincoln you must first develop within your own mind a conception of the painting. You decide whether you are painting the rail splitter, the Indian fighter, the weary war president. You examine paintings, photographs, and various pieces of art representing the great emancipator and then you start to work with brush and paint and canvas. But there is nothing in the painting process that tells you whether you are right or wrong and your success as a painter depends upon how closely the final product represents in the concrete the preconceptions that you started with.

Let us review some of the recent achievements of science. The outstanding discovery in the realm of physics has been the conversion of matter into energy so beautifully described by the Einstein equation, namely, $E = M C^2$ where M is the mass of the matter destroyed and C is the velocity of light. The velocity of light is 186,000 miles per second and this number squared, is 35 billions. So even if the amount of matter destroyed is small the energy liberated is very large. The discovery of the conversion of matter into energy rests upon a half century of basic research. At the turn of the century, studies made in connection with the element radium, revealed that this element was giving off energy to its environment in the form of strong X ray-like penetrating radiations called gamma rays, negative electrical particles called electrons and positively charged atoms of helium which are called alpha rays. These helium particles were thrown off from radium with a velocity of 10,000 miles per second and represented at the time of their discovery the greatest concentration of energy known to man. Comparison of the energy of the steam particle with the alpha particle reveals that the alpha particle contains approximately 400 million times as much energy as the steam particle. Rutherford bombarded the element nitrogen with this high energy alpha particle and found hydrogen atoms were formed as a result of the bombardment. This was one of the great fundamental discoveries of the past half century. In following up this kind of experiment it was found by Bothe and Becker in Germany, that when the element beryllium was bombarded in a similar fashion, a strong penetrating radiation was given off which was erroneously interpretated by the German workers as being a type of X ray. Chadwick in England corrected this impression by showing that the beryllium under bombardment with the alpha particle was giving off an electrically neutral particle of about the same mass as the hydrogen atom but with a velocity of approximately 10,000 miles per second. Workers then began to bombard the elements with this neutral particle. It was in the course of this kind of experimentation that it was discovered that when natural uranium is struck by the neutron some of the uranium atoms go to pieces and elements of smaller atomic weight are found in the debris. Matter is destroyed and tremendous quantities of energy are liberated. This is the work of Enrico Fermi in Italy and Otto Hahn in Germany. On the basis of these experiments, atomic bombs have been built, two of which have destroyed Japanese cities, and high temperatures have been made possible which approach those of the sun. These experiments are also the basis of the great effort which is being made today to work out peaceful uses for this energy in the form of electrical power, space heating, and many other uses which we could describe if the time were available.

It has been known for a number of years that the energy of the stars is primarily the result of light atoms such as hydrogen colliding with each other with tremendous velocities at very, very high temperatures resulting in the formation of helium and the destruction of a certain amount of matter in the process.

Attempts are now being made to realize experimentally the reactions producing heat in the sun and stars. There, at temperatures of ten to twenty million degrees centigrade, atoms of hydrogen stripped of their electrons strike each other with such force that the nuclei combine to form helium. Experiments in Russia, the United Kingdom, and the United States indicate some success in duplicating this process in the laboratory. Deuterium gas (an isotope of hydrogen having an atomic weight of 2) is held in a container under a very low pressure of 4 ten thousandths of a millimeter. A current approaching 200,000 amperes which lasts only 4 millionths of a second is discharged through the gas and is repeated every ten seconds. Temperatures approaching 5 million degrees have been obtained. Under these conditions the deuterium atoms lose their electrons and the positively charged stream of nuclei is constricted away from the sides of the container. Some combination of nuclei takes place with the liberation of neutrons. There is reason to believe some helium may be formed with the liberation of energy. So far the energy liberated is a very small fraction of the energy used, but there is every reason to believe we are witnessing the birth of a new age —that of man-made thermonuclear reactions, until now known only in the sun and stars.

In 1831 Faraday demonstrated with very simple apparatus that plunging a magnet through a coil of wire, gave a momentary electric current. The electrical industry grew from this experiment. The significance of these modern experiments is that they may open the door to vast quantities of energy.

The standard of living enjoyed by any country is directly related to the amount of energy which is available to the people of that particular country to carry on its work. If you want to dramatize the differences in the standards of living between India and the United States, there is probably no better way to do it than to indicate that in India the per capita amount of energy available to do the work of the Indian people is about 6,000 large calories per day. The per capita daily amount of energy available to the people of the United States is roughly estimated at 120,000 large calories per day. The advent of atomic power from the conversion of matter into energy, growing out of the experiments which we have discussed, now brings about the possibility of almost unlimited power for all of the nations of the earth, and therefore the possibility of a higher standard of living for all the people of the world looms large today.

I say "possibility" because the establishment of an atomic energy program requires a large capital investment. Where can this capital be found? In the underdeveloped countries where 90 per cent of the people are engaged in elemental agriculture capital growth takes place slowly. For this reason it is possible that the gap between the highly industrialized nations of Europe and North America and a country such as India will widen with time unless ways and means are found for increasing the capital from outside sources.

Let us take a brief look at the field of biochemistry. In the field of biochemistry the work that has been carried on in the field of large molecules commands attention. I should like, however, to explore for just a moment the new knowledge which we are receiving in connection with the highly complex large molecules called proteins. These proteins are made up of something like 20 to 25 basic units called alpha amino acids. They are combined in different orders in different molecules and obviously if you have 20 to 25 units you can arrange them in an enormous number of different ways. As a matter of fact, if you have 18 such units you can arrange them in 10^{23} different ways. It has always seemed to the organic chemist that the problem of understanding the order in which these units are put together was so complex that man probably never would be able to unravel the problem and yet within the last few years that is exactly what has been done. One of the recent Nobel prizes in the field of chemistry went to Professor du Vigneaud for determining the complete structure of one of the proteins of the pituitary body. Dr. Li of the University of California has recently indicated the order in which some 39 amino acid molecules were arranged in one of the other hormones from the hypothesis.

Some of the recent work of Professor Stanley of the University of California in connection with viruses has indicated tremendous advances in understanding the chemical structure of these very complex bodies. It is in this field of large molecules that we have every reason to believe that the key to the cancer problem will be found.

In the field of biology the area of genetics is opening up very rapidly insofar as basic understanding is concerned. The new tools of biochemistry and biophysics are giving us the opportunity to carry out work in this field undreamed of a few years ago. As a result, new varieties of barley, for example, have been developed by irradiating the plant which gives a higher yield, stronger straw, and greater resistance to disease. In the mustard plant changes have also been brought about genetically which have given very large increases in yield. This field is in its infancy. As a result of studies in the field of radiation genetics, science is now not only pointing to the possible results that may be of benefit to mankind coming through work in the field of radiation genetics, but is also setting up a very definite warning against what may happen if in the age of atomic power and atomic bombs we are not careful about powerful radiations altering some of the genetic characteristics of man himself.

It is very important to note here that when changes are brought about in the genetic make-up of a plant, for example by using ionizing radiation from these radioactive materials, that most of the changes will result in either the death of the plant, stunted growth or characteristics less desirable than those of the plant that was used in the original experiment. But every once in a while, every once in a great, great while, a change will occur which will give us a better variety of plant through these radiations. An illustration of the complexity of the problem might be given in this possible parallel. Suppose than an office boy using a bean shooter is shooting beans at the typewriter, while a secretary is transcribing the speech of a well-known speaker. It is obvious I think, to all of us, that most of the time striking a key with the bean would introduce a letter which without any question would not add anything to the composition of the speech. But I think all of us can imagine that it might be possible, for example, that the bean shooter might strike a letter that would alter a word in such a way that the speech might be a better speech. Certainly this would be a rare occasion but it is a possibility. This illustrates something of the problem of getting better varieties through radiation. Now of course in the plant world we have available to us thousands upon thousands of seeds for radiation and the same is true of course with microscopic forms of life. And here some changes can be brought about which are for the better. But with a limited population as is the case with animals, I think that you can see that the chances of getting better varieties is really very, very small indeed.

These examples of significant work that is going on in the physical and biological sciences today are typical of course of a great many that might be described if time permitted. What are the implications for education? Surely one thing that stands out is the fact that all of our sciences —physics, chemistry, biology— are becoming increasingly quantitative in character. As information becomes quantitative it becomes subject to mathematical analysis and to description in mathematical terms. Mathematics is the language of quantitative data. This means of course that in our schools for those who are going to go into technical work, mathematics becomes increasingly a necessity. Our public schools have done a remarkably fine job in the field of teaching reading, and it is obvious now that some very fundamental work must be done in the field of teaching arithmetic. I am not ignorant of the progress that has been made, but research must be intensified. Our social organization has been undergoing change. Numbers today for the youngster in the kindergarten and early primary years are related to television channels, radio wave lengths, telephone numbers, license numbers, house numbers, in all of which cases the number has no quantitative significance. The research that is taking place today at the University of Illinois, under a grant from the Carnegie Foundation, in the mathematical curriculum for the ninth, tenth, eleventh, and twelfth grades, is indeed promising. But much more research work needs to be done in the early grades, especially I would say from the fifth grade to the ninth grade because it is here that the antagonisms and the distaste for mathematics seems to be born.

In the opinion of many qualified scientists, biology may well be the next field in which great progress will take place. Biology is a very complex field in which research problems have many unknown factors and many variables. It is a field that is ripe for great advances because new tools are becoming increasingly available for use of investigators. These are the tools of biochemistry and biophysics and radiochemistry.

Traditionally the effective tools have been the microscope, with dyes as secondary tools. The emphasis has been on morphology and classification, and ecology. The underlying theory which has given guidance to research has been the theory of evolution. This gave a strong stimulus to the study of taxonomy, comparative anatomy, and embryology.

The new fields are the detailed structure and chemical reactions which characterize the protoplasm of cells and tissues. The new tools are the electron microscope, the spectroscope, ultramicrotomy (cutting biological material into sections so thin as to permit its study with the electron microscope). The radioactive isotopes are also powerful tools for metabolic studies.

It would seem to me that serious consideration must be given to the high school and college curriculum in biology. It is important that the high school student who has talent in mathematics, physics, and chemistry should be aware of the possibility of using these tools in exploring the field of biology.

Basic research has as its objective to understand the world about us with no other objective than to know; it is the kind of research that grows out of pure curiosity. This kind of research has found its home very largely in Europe, but today this responsibility is increasingly falling on the United States. The recent tremendous advances that Russia has made in the development of technical skills and engineering has undoubtedly precipitated a crisis in the minds of many people. I do not share this anxiety. It does seem to me however that it can be a stimulus to increase the efforts that we can make and should make in this field. It has many implications for education. It means at the elementary level that curiosity must be fostered. It means that asking students to merely repeat experiments in cookbook fashion must be increasingly eliminated from our educational program. I think if once we begin to explore the possibilities of rewriting the textbooks and reorganizing the experiments we shall find great fun in this task.

It was my privilege to teach sixth grade students one afternoon a week for a period of three years. I never had more fun.

Let me just describe one situation that took place, and I think you will see what I mean. One of these afternoons I took a Pyrex test tube, placed some ice in it and asked the youngsters what they thought would happen if I heated it in the flame of the Bunsen burner. Almost with one voice they said:

"The tube will crack."

To their surprise they found that it didn't crack, the ice melted. We wrote an equation on the board in their own language:

Ice + heat = water

We then heated the water to the boiling point and noted the steam which was formed, and again we wrote an equation in their own language:

Water + heat = steam

We then took some paraffin wax and I asked the youngsters what they thought would happen if I heated the wax. From their experience of course with the burning candle they told me it would melt. We heated the wax, it did melt. We wrote the equation:

Wax + heat = watery wax

The question: "What will happen if we heat the liquid wax?"
The answer: "It will form steam wax."
We heated the wax, the wax did become "steam wax." I then placed some pieces of rolled sulfur in the tube and said:
"What do you think will happen if we heat the sulfur?"
The answer: "It will form watery sulfur."
We heated the rolled sulfur, it became watery sulfur.
The question: "What do you think will happen if we heat the watery sulfur?"

The answer: "It will become steam sulfur."

We heated the liquid sulfur and to their surprise it solidified.
"Let's see that again" they said with one voice.

Now I am not holding myself up as a master teacher, I am merely trying to indicate what I mean by organizing experiments to stimulate curiosity.

I then asked one of the youngsters what he made of all of this. I shall never forget his answer. He spoke with a kind of a drawl.

"Well," he said, "it seems to me what it means is that just because you know something about water or ice and wax is no sign you know anything about sulfur."

What wisdom!

Let us seek balance in our educational programs. One of our outstanding dangers is that we tend to go to extremes in times of crisis. Many of us can remember the strong forces to eliminate the teaching of foreign languages in our schools during and after World War I. Today we see the folly of this attitude. Today the success of Russian scientists in putting satellites into space is giving rise to strong forces to emphasize the physical sciences and mathematics. Up to a certain limit this is good. We need to periodically review our work, but let us not forget the social sciences and the humanities. May I point out some examples from the work of a man who is working entirely in the realm of psychobiology, Professor Richter of the Johns

Hopkins University. Professor Richter for many years has recognized the fact that rats are very sensitive to their well-being and seemed to be able to react in a way that cultivates their well-being. For example, if rats are given a choice of many different fluids to drink and among them various strengths of alcohol, the rat will not touch alcohol in greater concentration than 6 per cent. Or let me give you another example. If you remove the pancreas from a rat, that rat becomes diabetic. It becomes necessary to revise the diet from the normal diet for both rats and human beings to a modified diet that will conserve the strength of the diabetic. We have worked on this problem for decades. When you do this to the rat, if you give him an opportunity to balance his own diet by placing in front of him isolated proteins, fats, carbohydrates, mineral salts, and water, and vitamins, in the course of a few days he will arrive at a balance that is just as good as we human beings have been able to work out after decades of study. Another example. If you remove the adrenal gland from rats they develop the same symptoms as man develops when that gland is destroyed by tuberculosis. This in the human, produces Addison's disease. Now among the many symptoms of this disease that it took us many, many years to learn is that under these conditions the potassium salt content of the blood rises and the sodium salt content of the blood falls. And we have learned to correct this and make the patient with Addison's disease more comfortable by removing foods high in their potassium content and emphasizing ordinary table salt in the liquids which the patient drinks. It took us decades to learn this. If you perform this operation on the rat and give him a free choice of foods, within 48 hours he refuses to take potassium foods and he emphasizes the salt content in his diet.

Now let me give one for you to think about. If you give a rat a free choice of fluids, coffee with or without sugar, with or without cream, with both, coca colas, various kinds of drinks that only you would know about, and tomato juice, you will find that the rat will drink approximately twice as much tomato juice as any other fluid you put in front of him. Why? What is there in tomato juice which makes him choose this? Is there something here, something lacking in the diet which is furnished by tomato juice? I leave the problem with you.

Now I want to discuss a new field that is just opening up and which is very hard to describe. Let me attempt it by outlining some recent experiments. Professor Curt P. Richter, of Johns Hopkins Medical School, in a paper presented recently before a memorial seminar in honor of the late Professor Walter Cannon, begins his paper with the following statement:

> 'Voodoo Death' —that is the title of a paper published in 1942 by Walter Cannon. It contains many instances of mysterious, sudden, apparently psychogenic death, from all parts of the world. A Brazilian Indian condemned and sentenced by a so-called 'Medicine man,' is helpless against his own emotional response to this pronouncement —and dies within hours. In Africa a young Negro unknowingly eats the inviolably banned wild hen. On discovery of his 'crime' he trembles, is overcome by fear, and dies in 24 hours. In New Zealand a Maori woman eats fruit that she only later learns has come from a tabooed place. Her chief has been profaned. By noon of the next day she is dead. In Australia a witch doctor points a bone at a man. Believing that nothing can save him, the man rapidly sinks in spirits and dies.
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> Cannon made a thorough search of reports from many primitive societies before he convinced himself of the existence of voodoo deaths.

Professor Cannon then asked himself the question: "How can an ominous and persistent state of fear end the life of man?" Having accepted then the possibility of "Voodoo Death" Professor Richter proceeded to set up experiments trying to place limiting values on this preconception. His experiments in my opinion are fundamental. He found, for example, if he trapped rats, wild rats, in a sort of leather bag which provided ample air for their living purposes but kept them trapped, they struggled for awhile, then apparently gave up the struggle and died. Why did they die? Not for lack of air, not for lack of stored chemical energy in their muscles. What physiological and psychological processes were involved? If one repeats the experiment, only this time after the animal has made a struggle he is temporarily liberated, and then trapped again, this second time the struggle goes on to complete exhaustion, a much longer struggle than the initial one. The crux of the experiment apparently is that if the rat has reason to believe, by virtue of a single experience, that the situation is not hopeless, he makes a struggle far beyond what he would make and lives much longer than he would ordinarily do under the same conditions. The implications of this kind of study for the world in which we live which is one dominated by fear, must be obvious.

Science and technology lead to engineering and large-scale production with tremendous implications on our social organization. Eventually this calls for social judgments. No better illustration of this can be given than the question of radioactive fallout which is a difficult problem before the world today.

We recognize in radio and television marvelous instruments for the education of young and old. Just last Sunday we were given the opportunity of listening to a fine interview with Mr. de Valera of the Irish Republic. We were given an opportunity to review by way of television some of the life of Mahatma Gandhi. On the other hand, we also know the abuses which take place through the same medium of communication. We are led to believe that certain drugs will take care of us when we are ill through the most false kind of presentation. These call for social judgments. Where will we develop these social judgments? In science? No. Science is not interested and cannot be interested in social judgments. These are value judgments. Where will you find a finer dramatization of the age-old problem of how to do justice without doing an injustice than in Shakespeare's Hamlet? What kind of foreign policy should the United States have? Perhaps we should listen to Immanuel Kant making his plea to act, to act, to act, so that our actions may become the standards of conduct. When we are being placed as educators under pressures to teach the law of the thing in terms of the physical sciences to the neglect of the social sciences and the humanities, shall we listen to Emerson when he warned us:

> There are two laws discrete,
> Not reconciled, —
> Law for man, and law for thing;
> The last builds town and fleet,
> But it runs wild,
> And doth the man unkind.

When we are under pressure by the crowd to think and work with the crowd rather than to maintain our independence in our thinking, should we listen to Emerson:

> It is easy in the midst of the crowd to be true to the crowd's opinion; it is easy in the solitude to be true to one's own, but the great man is he who in the midst of a crowd keeps the independence of the solitude.

What to do about it? It is obvious that technology will play an ever-increasing part in our culture. The teaching profession will be given heavy responsibilities for preparing our young people to play their part in this world of change. Young people having talents in the field of mathematics must be given the opportunity to grow in this field. They must also be given the opportunity to become aware of the increasing importance of mathematics to physical and biological science. At the same time the door must not be closed to young people having a "blind spot" for mathematics. History shows many examples of great creative research work in the field of the physical sciences by those who are not highly trained in the field of mathematics. There is much research to be carried on in fields that are not yet quantitative as I have tried to show.

For the teacher it means better preparation and this means the opportunity for advanced study. Our universities must re-examine their requirements for the master's degree for teachers who have only two years' preparation in given subject matter fields. A comradeship which has been broken during the past decade or so that existed between the university teacher and the high school teacher must be re-established. For the citizen it means that our teachers must be paid yearly salaries commensurate with the responsibilities that they carry. The prestige of the teacher must be such that the profession will attract young people from all economic sectors of our society. Perhaps in concluding I should paraphrase George Eliot by saying: "Let us not be pessimists because educators have done a magnificent job in educating our young people to work within the framework of democracy: let us not be optimists because optimism can dull our sense of what is critical and what is significant in a changing world and lead us into a chronic state of mediocrity. Let us rather be ameliorists, that is, if things in education are not as they should be all of us will lend our hands, our heads, and our hearts to making them so."